Information and Communication Technology in Public Schools

©2005

NOVA SCOTIA
Department of Education
Learning Resources and Technology

Information and Communication Technology in Public Schools

Table of Contents

Executive Summary 1

Section A: From the Literature 2
- Does ICT Improve Student Reading? 3
- Does ICT Improve Student Writing? 3
- Does ICT Improve Learning of Mathematics? 4
- Does ICT Improve Learning of Science? 5
- Does ICT Improve Learning in Other Curriculum Areas? 5
- Does ICT Improve Student Motivation and Attendance? 6
- Who Uses Computers? 7
- What is the Role of Professional Development and Leadership? 9

Section B: From Nova Scotia Schools 12

Section C: Discussion 22

Recommendations 25

Bibliography 26

Copyright 2005, the Crown in Right of Nova Scotia, as represented by the Minister of Education, Nova Scotia Department of Education, Box 578, Halifax, Nova Scotia B3J 2S9.

No part of this book may be reproduced in any form without the written permission of the Minister. Photocopying or reproducing electronically or mechanically in any other way parts of this book without the written permission of the Minister is an infringement of the copyright law.

Executive Summary

Computers and other components of information and communication technology (ICT) have supported student learning in schools in Nova Scotia since the 1970's. Beginning in 1984, the Department of Education took steps to formalize the integration of information technology in support of learning across the curriculum. In 1999, the *Vision and Outcomes for the Integration of Information Technologies within the Nova Scotia Public School System* described the philosophical and curricular basis for integration of technology and included specific outcomes for learners at key stages. Several of these technology outcomes have been integrated within subject-specific curriculum documents. In addition, other curriculum documents describe outcomes for specialized technology-related courses such as Communications Technology, Multimedia, Film and Video, and Computer Programming.

The "P3[1]" school construction process, and later the Information Economy Initiative, provided the technology, software, professional development and technical support necessary to begin the implementation of the vision and to achieve the outcomes related to the classroom integration of technology. These models have continued in schools through the new school construction process. Over time the Department's focus has shifted from computer literacy as an end in itself toward the integration of ICT to enhance student learning and achievement of curriculum outcomes. Research demonstrates that while information technology of itself is no panacea for the public school classroom, its effective use can significantly improve learning for many students.

An overarching caveat is that much of the research related to classroom use of ICT lacks the rigour and experimental design which is necessary to assess objectively the impact of technology. However, there is mounting evidence that when students use computers, they take more initiative outside class for research, work harder on assignments, help one another more, and learn reasoning and problem-solving skills faster. The biggest gains are reported when students, supported by competent and knowledgeable teachers, use more open-ended computer tools and simulations to explore authentic problems. Consistent themes in the research and in the anecdotal evidence include the importance of sufficient access to technology, adequate professional development and technical support for teachers, and strong leadership by educational administrators.

This paper has been prepared by staff of the Learning Resources and Technology Division of the Public Schools Branch, with input from teachers and technology coordinators from school boards in Nova Scotia. It is framed by four questions. Is there a research basis for use of information and communication technology (ICT) in public school classrooms? Are these research findings reflected in ICT integration in schools in Nova Scotia? What conditions are necessary to enable effective use of ICT? How can lessons from exemplary classes be transferred to other classrooms and schools?

This paper comprises five components: a review of the formal research literature; anecdotal evidence from schools in Nova Scotia; discussion of the implications for policy development related to ICT in public schools; recommendations; and bibliography.

---

[1] P3 - Public Private Partnerships

Section A: From the Literature

This paper has been prepared by staff of the Learning Resources and Technology Division of the Public Schools Branch, with input from teachers and technology coordinators from school boards in Nova Scotia. Citations were selected to be representative of trends in research findings. The paper attempts to answer four questions: Is there a research basis for use of information and communication technology (ICT) in public school classrooms? Are these research findings reflected in ICT integration in schools in Nova Scotia? What conditions are necessary to enable effective use of ICT? How can lessons from exemplary classes be transferred to other classrooms and schools?

Computers and other components of information and communication technology (ICT) have supported student learning in schools in Nova Scotia since the 1970's. Beginning in 1984, the Department of Education took steps to formalize the integration of information technology in support of learning across the curriculum. In 1999, the *Vision and Outcomes for the Integration of Information Technologies within the Nova Scotia Public School System* described the philosophical and curricular basis for integration of technology and included specific outcomes for learners at key stages. Several of these technology outcomes have been integrated within subject-specific curriculum documents. In addition, other curriculum documents describe outcomes for specialized technology-related courses such as Communications Technology, Multimedia, Film and Video, and Computer Studies.

The "P3" School Construction Process and later the Information Economy Initiative provided the technology, software, professional development and technical support necessary to begin the implementation of the vision and to achieve the outcomes related to the classroom integration of technology. These models have continued in schools through the Crown Construct process.

Over time the Department's focus has shifted from computer literacy as an end in itself toward the integration of ICT to enhance student learning and achievement of curriculum outcomes. It is an appropriate time to review the progress which has been made in the integration of technology and to assess the impact on student learning.

This section of the paper is based on a review of the research literature with an emphasis on studies which have been published since 2000. That date was selected because there has been such a change in the types of ICT use and levels of access to ICT in later years.

Research demonstrates that while information technology of itself is no panacea for the public school classroom, its effective use can significantly improve learning for many students. In a national survey, the Canadian Teachers Federation reports that if students use computers, they take more initiative outside class for research; work harder on assignments, and help one another more; and learn reasoning and problem-solving skills faster (CTF 2003). While the main reason to consider the integration of ICT in public school is to enhance student achievement of curriculum outcomes, one author argues that ICT may increase our capacity to compete in the new economy, improve education, and reduce social inequities (Pelgrum in Corbett 2002). The most frequently reported uses of computers in public school classrooms are research/Internet (40%), word processing writing/journals (36%), presentations (11%), resources from the web (9%) and drawing/graphics (7%) (CTF 2003).

Several studies demonstrate a correlation between use of information and communication technology (ICT) and increased scores on standardized tests in reading, mathematics and writing while contributing to a knowledge building pedagogy (Corbett 2002). ICT increases learner-control, motivation and connections to the real world. It can enhance

student achievement according to a variety of measures (NSREL 2004).

Research for this paper was assisted by several comprehensive meta-analyses of information technology in education which were presented at the Information Technology and Learning Symposium in 2002, which was funded by the Pan-Canadian Education Research Agenda (PCERA). In addition, LRT staff surveyed research from many online and print journals and research reports. Like much research in education and social sciences, many studies lack the experimental rigour which permits definitive conclusions. However, the following sections describe the impact of ICT in specific areas.

Does ICT Improve Student Reading?

Evidence about the effectiveness of ICT on literacy learning is mixed. Some studies have been systematic enough to make objective evaluations, but many others have been insufficiently rigorous or focussed too narrowly on only one aspect of literacy (EPPI-Centre 2003). At least one researcher has found that ICT can support higher levels of literacy of learners, and in so doing reduce disaffection, anti-social behaviour and even crime later (Passey 2004). There is also substantial research indicating that individual software titles are effective in developing specific skills in specific learners, for example, those who are socio-economically disadvantaged, reading-delayed, inmates, adults in literacy training or ESL students (Morgan 2002).

There is a positive correlation between reading scores on OECD's Programme for International Student Assessment (PISA) and having a computer or a link to the Internet at home, but the best predictor of reading score is the student's reported joy of reading (Bussière 2002). In a 2004 study, researchers found that students with more than one computer at home perform significantly worse on PISA after controlling for other factors like family background, parents' education and location of school. The authors argue that computers at home may distract students from learning and can be used for purposes other than learning (Fuchs 2004).

Several studies indicate no difference in student reading of text on paper compared to a computer screen (MacArthur 2001), but students with learning disabilities comprehend significantly better (up to one grade level improvement) when text is highlighted on a computer screen and read aloud (bimodal presentation.) Some drill and practice software applications have had positive results with students who suffer severe difficulty reading as a result of their learning disabilities, but only when coupled with effective teaching strategies over an extended period of time (Morgan 2002).

Researchers in the Center for Applied Special Technology demonstrated that students who used supported, digital versions of age-appropriate novels had greater comprehension than a control group who did not receive computer supports. The former group also showed higher levels of engagement and improved 'on task' behaviour (O'Neill 2004). The International Reading Association now includes ICT literacy in its list of literacies and believes that educators have a responsibility to effectively integrate these technologies into the literacy curriculum in order to prepare students for the future (IRA 2002).

Reading improves as a result of the use of computers combined with instruction in, and practice with, reading strategies and technology that highlights text on screen and reads it aloud.

Does ICT Improve Student Writing?

Teachers, parents, and students in a British Columbia study believe that student writing has improved because of the use of laptop computers and that this improvement is strong and consistent. 92% of students produced writing samples that met expectations on the BC

Performance Standards compared with 70% on the pretest and students whose writing exceeded expectations increased from 0% in September to 18% in May (Jeroski, 2003).

When students receive instruction in writing strategies and how to take advantage of the editing features within word processing software, they make more and better revisions and improve the quality of their papers (MacArthur 2001). Children with high access to a computer were more likely to write better, to write more, and were more likely to edit and revise their writing. Further, that improvement was better for accelerated students than for remedial writers (Ungerleider 2002). When students use word processing software coupled with instruction in the writing process, student writing improves significantly (SIIA 2000). Teachers and learners from primary to high school reported that ICT has a motivational impact on research, writing and editing and results in more engagement (Passey 2004).

Electronic mail provides opportunities for students to develop literacy skills because it creates a motivating and authentic experience for both reading and writing. Students use e-mail to build relationships with new friends, or assume new social roles and voices in class discussions. Students tend to speak out more often on e-mail and feel less intimidated than in face-to-face discussions (Tao 2000). Students test their viewpoints through contact online with individuals who hold different views and perspectives. E-mail also provides a built-in opportunity to reflect before replying (Tao 2000).

Students with disabilities found it easier to express themselves and to make friends with other students (including those without disabilities) through e-mail and chat rooms online. By using a computer to help visualize abstract concepts, autistic children also demonstrate enhanced learning (Venezky 2002). Special education teachers report that their ICT-using students have increased both the quality and quantity of their writing. Their use of laptop computers removed the motor coordination challenge of writing and allowed them to produce work that was easy to edit and looked as good as the work of their students without disabilities (Harris 2004). Passey (2004) reports that spelling and layout was better in an experimental student group using word processors, and their project work improved. In addition, a wide range of assistive and adaptive devices, such as special keyboards, switches and voice recognition technology, are currently available to assist learners with physical needs to actively engage in writing using computers.

In addition to helping students with writing itself, computers and multimedia authoring can be a useful diagnostic tool for teachers to use at the formative stages of learning literacy (McFarlane et al in EPPI-Centre, 2003).

Does ICT Improve Learning of Mathematics?

When computer applications are used to teach higher level cognitive skills (e.g. simulations and open ended applications), there is a positive correlation with achievement in mathematics (SIIA 2000), but when computers are used to drill lower level skills, there is a negative correlation with achievement (Ungerleider 2002). Ungerleider also emphasizes that use of computers is no substitute for qualified and caring instruction. The reported impact of technology on student learning in mathematics varies greatly depending on the age of students (Ungerleider 2002). Innovative and challenging uses of ICT can improve students' data-handling skills, and their ability to construct complex models (Cox 2003).

Students who use software, such as *Geometric Supposer*, explore geometric relationships across a whole range of instances involving angles, triangles and quadrilaterals (Gardner 2004b). Students who receive geometry instruction using a constructivist approach that integrates computer applications achieve

stronger understanding of geometry concepts than students who receive more traditional instruction (Funkhouser 2002). In a study of criteria which affect students' ability to conjecture in geometry, the pedagogical approach used in the software was less significant in student achievement than prior math ability, school learning climate and time allocated to independent investigation (Elchuck 1992).

ICT does seem to improve academic achievement and school social environment when used to develop understanding of higher order concepts and when teachers are proficient enough in its use to direct their students toward productive and worthwhile tasks (Wenglinsky 1998). In some Math classes, ICT enables a higher level of analysis than might otherwise be possible using conventional means (Ofsted 2004). For example, using computers, students can increase their understanding by manipulating data in tables and interpreting the resulting changes in graphs of that data (Higgins 2003).

Common contributors to the effective use of ICT include a focus on higher order skills, sufficient access to technology, time to explore, and teachers who are prepared to lead students to higher levels of understanding.

Does ICT Improve Learning of Science?

More frequent use (1-2 times per month) of computers to collect data or to analyse data was associated with higher scores than less frequent use (less than once a month) (NAEP, 2000).

Physics students at Acadia University, participating in studio labs, constructed experiments using science interfaces and evaluated data using computers. As a result, they were consistently happier with their course and outperformed students in conventional classes. The ICT supported physics students undertook more investigations and were better able to generalize what they had learned (Williams 1997). These results were later confirmed in a more formal study (Williams 2003). Introductory physics students who participated in Microcomputer-Based Interactive Lecture Demonstrations at the University of Oregon and Tufts University demonstrated at least four times the understanding of physics concepts as students in conventional lectures. It is significant that student understanding persisted and even improved slightly six weeks after the demonstrations. The researchers noted that in the absence of microcomputer based demonstrations, most students did not understand the concepts of kinematics and dynamics (Sokoloff 1987).

In one case study, a grade 4 class which developed an experimental model of oil pollution and its effects on sea birds, produced a videotape to explain their project. Their final project included still photographs of their experimental birds before and after the experimental treatment. Thinking in pictures is important to developing long term memory and understanding (Wolfe 2001). Visual documenting and reporting is enhanced by computer software which is available in elementary and secondary schools across Nova Scotia; this curriculum-focussed computer software provides many opportunities to explore simulations in mathematics, science and social studies.

Does ICT Improve Learning in Other Curriculum Areas?

Computer simulations which have been developed to support the curriculum, particularly in sciences and social sciences, pose authentic and dynamic problems (Klieme in EPPI-Centre 2003) whose solution results in increased retention and understanding of concepts while engaging learners in solving real-life problems (Wolfe 2001). Some simulations can also record the student's problem solving strategies to provide diagnostic information for teachers. Gardner suggests that

immersing students in a technology-based simulation where they manipulate data or events can contribute significantly to their learning because students typically use these tools to extend their understanding in an apprentice-like, cooperative learning environment with multiple representations of data and the opportunity to assume different roles similar to those of skilled adult practitioners (Gardner 2004b).

Visually mapping information enhances students' storage and retention of information because it mirrors the structure used by the brain (Wolfe 2001). While there is apparently little learning advantage in using computer-based visualization techniques with middle school students, graphic representations created by them, using appropriate software, are a useful tool for teachers in the evaluation of student understanding about underlying concepts (EPPI-Centre 2003). Errors and misconceptions in concept maps signal incomplete understanding (Gardner 2004b). In this particular study, participating middle school students were distracted by the complexity of the visualization software. In Nova Scotia, elementary students are first introduced to *Kidspiration* and later use *Inspiration*, both powerful and user-friendly visualization tools that allow students to graphically organize and illustrate their understanding of concepts. It is expected that with such experience, these learners will be able to take full advantage of computer applications (as in easily modifying a diagram) to enhance their learning across the curriculum.

Grade 4 students whose teachers reported using computers for playing learning games had higher test scores than fourth-graders whose teachers did not. Grade 8 students whose teachers used computers for simulations and models–or for data analysis–scored higher than their counterparts without such ICT support, and Grade 12 science students who reported using computers to collect data, download data, or analyse data higher scores than students who reported never doing so (NAEP 2000).

A number of authors describe how classroom access to ICT leads students to take a virtual field trip of sites such as le Louvre, the Smithsonian Institute, the House of Commons, Canada's Museum of Civilization, or to participate in a simulated archaeological dig. While there is no research comparing real and virtual field trips, virtual tours are the only practical means by which students in most schools can participate in such rich learning experiences.

Students can use Geographic Information Systems (GIS) to interpret or manipulate complex data sets (Higgins 2003). Students who used GIS enhanced achievement of student outcomes and demonstrated improvements in science and attitudes toward technology (Baker 2002). In geography, ICT enhances geographical knowledge, develops skills with graphics, mapping, statistics and spatial analysis, and encourages communication with students in contrasting localities (Becta 2004). GIS can support a constructivist approach to teaching in which the teacher is a coach (Cameron 2004).

Does ICT Improve Student Motivation and Attendance?

Research emanating from Apple's Classrooms of Tomorrow (ACOT) projects indicates that technology motivates students to higher levels of achievement (Apple 2002). A number of other studies report a positive impact on motivation of student access to computers, but much of that impact can be explained by the collaborative learning process underlying the experience (Ungerleider 2002). Other studies report increased motivation, enjoyment and understanding, particularly amongst low achieving students who demonstrated increased interest and reduced non-task directed behaviour (Ungerleider 2002). Morgan, while acknowledging that several of these effects are difficult to measure, still reports benefits from computer use, including increased student self-confidence, better motivation, more frequent

feedback, greater learning enjoyment, reduced discipline issues and increased completion of more complex assignments (Morgan 2002).

Since the State of Maine introduced laptop computers for all students entering grade 7, student attendance is significantly up and detentions are down (Mahoney 200.). Teachers credit the use of laptops with improving the engagement of students with disabilities; increasing their motivation and their ability to work independently; and improving both class participation and interaction with other students and teachers (Harris 2004). Students who are typically unmotivated and uninterested in applying their reading and writing skills choose to engage in challenging, authentic learning tasks (Coiro 2003). Research also suggests that relevant ICT support helps weaker and low SES students more, as a result of their increased access to educational resources and their increased motivation for learning (Venezky 2002).

Some educators favour the development of project-based curriculum using ICT as a way of ensuring that students learn to deal with significant and complex problems. However, effective application of such curriculum requires that teachers alter both their pedagogical approach and their conception of how students learn. In addition, students must understand the real-world utility of the learning activities in which they are engaged (Legault 2002). This would further underline the need to fully embed principles and models of ICT integration into pre-service teacher education programs so that future teachers can see integration as an essential component of lessons, not just something extra to be added on after planning a lesson.

ICT helps motivate by providing a wider range of learners with more opportunities to experience success. However, ICT use has to be coupled with learning tasks that are appropriate to the curriculum, and with learning strategies appropriate to the tasks (Passey 2004). If one assumes that student achievement is related to student attendance and focus on task, then ICT activities which increase engagement will positively impact student learning.

Using ICT, learning activities for students can be more easily and effectively individualized to make them compatible with their learning preferences (Gardner 2004b). Digital learning activities and the World Wide Web are well suited for motivating students with a variety of learning styles. Technology facilitates a multi-sensory approach that engages and motivates learners for extended periods (Berson 2003).

Rather than seeking to endow ICT with special properties and powers it would be better to accept that the principal agents in the teaching and learning process are teachers and their students, and that if both parties commit to the use of what is undeniably a powerful tool, then improved learning is very likely to occur (Goodison 2002).

Who Uses Computers?

Teachers in different grades and subjects report considerable variation in their use of computers. One survey found that elementary teachers were twice as likely to use computers as a problem-solving or communication tool than high school teachers. Science teachers were two to three times as likely as math teachers and English teachers to integrate computers, as a research and problem solving tool, into their practice (Barron 2003). Teachers with less than five years experience were more likely to use GIS and were more likely to have been trained in the discipline in which they teach (Cameron 2004). Professional development for teachers must be planned and implemented to assist classroom teachers in deploying online research and other ICT tools professionally.

Several studies of high school students indicate that males continue to be more likely than females to use computers, while at the same time, the proportion of females studying

science, engineering and ICT is dropping (Looker 2002). In Nova Scotia in 2003/2004, participation by girls in high school technology courses varied from 34% in Computer Studies to 43% in Communications Technology. The Canadian Teachers Federation identifies 17% of male teachers in Canada—compared to 8% of female teachers—as innovators in ICT integrated education (CTF 2003).

Other studies based on Canadian data indicate that while males and females in Canada report similar levels of ICT use, males are more likely than females to create computer programs, use graphics software, electronic spreadsheets and desktop publishing. As a result, males are more than twice as likely as females to claim excellent computer skills (Looker 2002). In an analysis of data from the Youth in Transition Study, girls in public schools consistently underrated their ability in mathematics and computers while they reported excellence in writing and reading. Boys, on the other hand, more often reported excellence in problem solving, mathematics and computer skills. While these perceptions are not related to actual performance, they do affect the fields of post-secondary study and careers chosen by boys and girls (Thiessen 2004). Although the use of ICT probably has a greater positive effect on boys and enables them to shift to more concentrated learning activities over a longer period of time, this phenomenon does not seem to disadvantage girls (Passey 2004).

One third of teachers report that computers are essential and almost half report that computers are important to their teaching. That commitment declines somewhat as the age of the reporting teacher increases. Interestingly, older teachers are more likely than younger teachers to agree that computers are the future of education (CTF 2003).

Statistics Canada reports that 90% of Canadians have a computer at home, and of those, 70% have access to the Internet; but, in lower income groups, fewer than 25% had home access to the Internet. In November 2002, The Canadian Radio-television and Telecommunications Commission (CRTC) reported that 80% of Canadian households have access to broadband internet, although less than half of that percentage subscribe. Significantly, in rural areas, only 63% of households have access to broadband but more than half that percentage actually subscribe to it. Children from lower SES homes and in rural areas report less access to computers at home and lower levels of computer competency, but they are more likely to use computers in schools (Looker 2002). Access to online and computer-based resources in French and in Mi'kmaw lag far behind access to resources in English (Fournier 1994). Disadvantaged groups seem to lag behind in access to those aspects of technology that affect educational outcomes; there are significant inequities in exposure to higher order thinking skills and to teachers who have received professional development on technology use (Wenglinsky 1998). Even though teachers require focussed professional development to effectively extend the benefits of technology to all learners, these findings suggest that public schools play an important role in minimizing the digital divide in Canada.

The debate continues regarding computer deployment, either in computer labs or in smaller clusters in regular classrooms. While concentrating computers in labs is efficient in the case of ongoing use during specialized technology courses, placing computers in general access labs hinders integration within classroom teaching and learning and certainly impedes spontaneity (Fournier 1994). If computers are to be integrated fully with regular classroom curriculum, computers must be distributed amongst individual classrooms.

A number of sites in other provinces and states have adopted whole school or whole state laptop programs much like Acadia University in Wolfville where each and every student has a dedicated laptop computer. Public school examples to date include grade 7 and 8 students in Maine (Mahoney 2003), grade 7 pilot classes

in New Brunswick (2004), Peace River, British Columbia, and Eastern Townships School Board, Quebec (Sokoloff 2003).

Teachers' ICT use for curricular purposes is almost exclusively a function of their access to it; there must be ready ICT access in classrooms to maximize its effect on students' learning. That said, having one computer in a classroom is not sufficient access and will not permit much use by all students (Norris 2003). Ratios better that one computer per four or five students are necessary to ensure significant improvements in learning (NCREA 2004, Corbett 2002). Disessa (2000) suggests that the critical ratio is one computer per three students before core practices can be radically changed. The current ratio of classroom computers to students in Nova Scotia varies from 1:7 in grades 4-6 to 1:4 in grades 10-12, although the latter ratio is distorted by the number of discrete computer labs in high schools (Survey of computers in schools, NSDOE March 2004).

Guidelines in Ontario recommended 2.5 hours of access to computers per week from Junior Kindergarten to high school completion, or about 10% of the school day (Fournier 1994). An original target for a Nova Scotia ratio of 1:5 was based on providing access to computers for at least 20% of the school day, which would have averaged one class period per day.

Regular access to computers is a necessary precondition for teacher use of ICT in the classroom, but without consistent technical support and suitable professional development, that access is unlikely to translate into the effective use of ICT in the classroom by students (Breuleux 2002). A recent report describes workable ratios of technical support which range from 1 technician to 100 computers to 1 technician supporting 200 computers (Dickard 2003). In Nova Scotia, 77 technicians support approximately 40 000 computers (a ratio of worse than 1:500).

In order for technology-based learning activities to have the greatest impact on student attainment, learning activities must have clear outcomes and use ICT appropriately. Learners must have the necessary ICT skills, and adequate seat time for sustained work using ICT either individually or in small groups. Moreover, teachers must be skilled in engaging learners in reflection and the analysis of their own learning (Stevenson 2004).

What is the Role of Professional Development and Leadership?

ICT can be a powerful lever for change when new directions are carefully planned, adequately funded, and provided with appropriate staff and support systems. Integration of ICT must be integrated with other curriculum change (Venezky 2002). Rarely can improvement in student learning be attributed to ICT alone; before ICT can effectively support learning, pedagogy must move from teacher-focussed instruction towards student-focussed activities (Corbett 2002).

Michael Fullan argues that large scale reform will not occur without a strong teaching profession and the functional coherence of individual professional development plans and education program goals and activities (Haughey 2002). Fullan also points out that systemic change requires long term commitment (up to five years). Studies confirm that mere access to computer equipment by itself does not ensure that the equipment will be used regularly or effectively by teachers and students (Legault 2002, Fournier 1994). The International Reading Association asserts that institutions must "provide sufficient time for teachers to develop proficiency in the new literacies of ICT" (IRA 2002).

Successful integration of information and communication technology by pre-service teachers is highly dependent on classroom ICT integration by master teachers during in-school practice teaching; on each pre-service teacher's level of computer literacy; on modelling of ICT integration by education faculty; and on the

degree to which, as a result, pre-service teachers are comfortable with ICT and value its effects. For effective integration to take place, teachers require both "technoinstrumental skill", and also "technopedagogical skill" (Karsenti 2002).

Teachers often report that they have not received sufficient professional development and technical support to integrate information technology in their classrooms, and French-speaking teachers are less prepared than English-speaking teachers (Morgan 2002, CTF 2003). The Canadian Teachers Federation reports that 75% of elementary and secondary teachers in Canada have received professional development related to using computers for instruction, but that this training has not fulfilled teachers expectations (CTF 2003).

One report suggests that students of teachers with more than ten hours of professional development related to integration of information technology significantly outperformed students whose teachers had five or fewer hours of training (NCREL 2004). Another suggests that teachers attending long courses (150 hrs contact time and 150 hrs private study) become highly proficient users of IT within their teaching (Govier in Slater 2004). The latter far exceeds the amount of professional development time available to most teachers. It is clear that teacher motivation and interest in the potential impact of ICT upon learning is driving outcomes within classrooms (Passey 2004). Professional development must be intensive and of high quality, because this training is such an important precondition for successful use of ICT (Wenglinsky 1998).

In 2003, the Conference Board of Canada published an Issue Statement entitled *Solving Canada's Innovation Conundrum*, in which it issued a call to action that would "encourage educators and leaders to have a passion for new and better ways of doing things and to provide access to new technologies and programs to learn". The shift in pedagogical style and perspective a goal such as this requires will only be accomplished by modifications to the training of teachers in technology that provides a framework integrating ICT with sound instructional practices to improve teaching and learning (Berson and Balyta 2003).

Leaders of professional development for teachers must ensure that participants have sufficient time and support to internalize the strategies which are being presented, including ICT. One writer suggests that while workshop leaders are usually able to demonstrate what they can do with a particular innovation, teacher participants are often left wondering what they can do with the innovation themselves (Diessa 2000). Professional development sessions must include sufficient time for teachers to apply their new skills and knowledge.

The ideology, practice and values of the teacher have a large impact on student attainment using ICT (Cox 2003). Teachers must be knowledgeable about both the curriculum and the software being used to support it. They must also strike the right balance between work at and away from computers (Ofsted 2004, EPPI-Centre 2004). School structures and separation of school subjects also have an impact on uptake of ICT. One author recommends block scheduling and 90-minute periods as the best scheme for the integration of ICT with public school curriculum (Peck 2002). The principal or local school administrator is also critical to successful integration of ICT; the principal must develop and maintain a learning environment which encourages and supports innovation (Venezky 2002).

With the rise of computers in classrooms has come a range of conflicting conclusions about the actual value computers bring to the teaching of reading, writing, and arithmetic. This is frustrating for some in education, but for others, blind faith in the educational benefits of technology is giving way to greater appreciation for an understanding when computers are useful and when they're not (MacDonald 2004).

In summary, the formal research indicates that student learning is enhanced by information and communication technology when teachers are well prepared and comfortable with both the technology itself and strategies to engage learners. Research also indicates that to truly improve student learning, there must be an ongoing, school-wide commitment to change, and effective modelling of good ICT integration in both classrooms and in pre-service teacher education.

Section B: From Nova Scotia Schools

The preceding section of this paper draws observations from the formal literature with an emphasis on those studies published since 2000. This section reports anecdotal comments from Nova Scotian teachers in response to requests for stories illustrating effective uses of information and communication technology in the classroom. This anecdotal evidence mirrors the research findings outlined above, in that the most positive learning impacts occur when pedagogically strong teachers embrace the integration of information technology in support of their already constructivist approach to curriculum. The impact of ICT on individual students can be measured in terms of their increased motivation to learn, to attend or to focus on school-oriented tasks; in their increased ability to communicate with each other and with a wider audience via the Internet; and in their growing ability to assimilate complex problems, such as those posed to them by computer-based simulations.

In Nova Scotia, there was no significant or general access to computers in secondary school classrooms until the first delivery under the Canada-Nova Scotia Information Economy Initiative in June 1999. Prior to this, what computers were available tended to be clustered in computer labs and mostly used to support specialized technology courses. At the end of the IEI deployment in June 2000, secondary schools had 6200 new computers, complete with curriculum-relevant software, technical support, professional development for teachers and a sophisticated wide area network, EDnet, which linked all schools. This situation was similar throughout North America and hence, much early research on ICT effectiveness in schools is not based on consistent ongoing and significant access by students and teachers.

To implement the Information Economy Initiative in Nova Scotia, a management forum involving one school board technology coordinator from each school board and the Director of Learning Resources and Technology was formed. This group, affectionately known as RoBoTS, has evolved into a forum for sharing where professional development coordinators and implementation supervisors can discuss strategies and best practices for integration of ICT across the province. This administrative model facilitates the communication of success stories and professional development models province-wide.

There has been much debate about whether to locate computers in classrooms or in labs. School visits and discussions with teachers have indicated that while teachers of dedicated technology courses use computer labs extensively, segregated labs discourage most classroom teachers from integrating computers in the curriculum. Many Nova Scotian schools have adopted a model of placing a few computers in each classroom with one connected to a projection device for small and large group exploration and presentations. Some schools in Nova Scotia supplement classroom computers with mobile carts containing wireless laptops. This mobile cart has the advantage of not requiring dedicated wiring for electrical power and network connections and is extremely flexible. One school reports that mobile computers are in almost constant use, are an integral resource to several classroom teachers, and provide the flexibility necessary to implement several innovative learning activities (Jim B., CCRSB).

Fine Arts

At an urban elementary school with a high population of English Second Language (ESL) and at-risk students, the music teacher uses music composition software to encourage and amplify her students' creativity and understanding of musical relationships and annotation. The software permits students, singly or in small groups, to compose original

music, play it back instantly over head-phones, and annotate it with familiar, concrete symbols, such as balls and birds. As a result, students concentrate on the musical relationship of notes in their music rather than the effort of performance or hand annotation (Gail T., HRSB).

Music students in six elementary classrooms wrote original music compositions with the assistance of music annotation software and virtual composers in residence and faculty at Acadia University. Composers in Virtual Classrooms (CIVIC) consulted more expert university music students to obtain feedback on their compositions. They also shared their compositions online with students in Vermont. The project engaged both public school students, teachers and university music education students as active learners (Dr. Ruth Morrison, Acadia).

Auburn Drive High School, an urban high school in Dartmouth, offers Digital Arts and Culture 11, which introduces small student teams to animation, virtual drawing, and production processes using integrated ICT applications in a project-based learning environment.

Language Arts: Writing

As early as 1985, a Nova Scotian school participated in a pilot project using telecommunications to link with schools in the United States. This project was part of a research study on the impact of computers and telecommunications on students with special needs. Even though this project occurred prior to the public availability of the Internet, students in the resource room of a local junior high school quickly adopted a computer for writing and exchanging information with their distant peers. Students who had previously been reluctant to write or use tools such as dictionaries, paid particular attention to the content and structure of their writing because they valued the opinion of this authentic, on-line audience. A secondary benefit was that students in the resource room were participating in a learning experience which was coveted by their more able peers (M. Jeffrey, NSDOE). General availability of computers and the Internet should permit replication of this effect in schools across the province.

In a SchoolNet Grassroots project, Grade 10 students in Cape Breton partnered with elementary students to compare life in Canada with life in the United States. Students who had never e-mailed or used a computer were looking up information about their country, the climate and their community to prepare information for their partners. Their teachers reported benefits from developing, through e-mail contact, mentoring relationships with younger students to help them develop literacy, data collection and research skills (Sandra L., CBVRSB).

In a Primary/One combined class at Sambro-Ketch Harbour Elementary, where *Kidspiration* software is installed on two computers from the Technology Recycling Program, beginning writers create word webs and outlines to help them demonstrate what they have learned about Nova Scotian animals in their Science curriculum. At another school, students in Grades 2 and 3 composed poetry on classroom word processors, then posted their verse to the Scholastic website. Their excitement at publishing for a world-wide audience provided a particular motivation for them to improve their writing skills, while the word processor facilitated the process of composition (Jill, AVRSB). Even the very young quickly learn to manipulate technology to express relationships between their ideas.

One teacher in an ICT- integrated elementary classroom reports the following benefits: on-the-fly mini-lessons and research; more easily customized curriculum; easier and more flexible grouping of students according to assignment, interest, or task; empowerment for different students by allowing them to become classroom leaders and assist others with learning; enhanced motivation and self-esteem through

publishing student work to a wider audience (Lorna B., HRSB).

Each student taking Grade 10 English at an urban high school in Nova Scotia is required to complete an assignment that introduces them to basic research skills such as using an online periodical database, an online library catalogue, an online encyclopaedia, as well as print sources to write their first formal essay and citing material properly. The teacher-librarian at this school reports that this assignment is making a difference to the students in terms of awareness of services available on the Internet or through the library. It is also making a positive contribution to their research skills and their writing skills as they learn how to write a good thesis statement and write a good short essay (Pat M., HRSB).

Language Arts: Reading

Creation of a "Book Buddies" web-page for Grade 5 class and the Grade Primary at one school combined the book buddy concept with ICT. The teacher collected a series of safe Internet links which used audio as part of the web story. Students could then accompany primary students to the computer lab, where they could enjoy the stories together. This activity became especially important in the literacy development of many struggling readers who were working with Grade Primary students (Chris, SRSB).

At Antigonish East, students in a Grade 8 classroom routinely take turns on their computer pod in the classroom to streamline the creation of reading responses for their Literature Circles. This use of ICT improves both the quality and quantity of their responses by taking the drudgery out of group editing and experimentation. Insofar as word processing software like Word and concept mapping software, such as *Inspiration*, support student reflection on what they are reading, this ICT use also promotes their reading comprehension (Wanda F., SRSB).

At another Nova Scotian school, children with Down's syndrome use computers to hear living books, which provide good models of oral language. After listening to the audio CD, *Just Grandma and Me*, one fairly non-verbal child began to greet people in the hallway with a crystal clear, properly inflected "Nice day, isn't it" (Nancy B., HRSB).

M. hematics

One grade 5 teacher created mental math drills using *PowerPoint*, and then used features in the software to increase the rate of presentation to correspond to students' learning. Students enjoyed the format and eagerly participated in the development of mental math skills (Lloyd M., SRSB).

Grade 7-8 students in Nova Scotian schools use the software, *Geometer's Sketchpad*, to explore properties of reflections. This software adds interactivity and dynamic change to Geometry activities, which multiply the opportunities participating learners have to discover the relationships between shapes. As a result, students achieve a more complete understanding of properties of shapes than they would using only pencil and paper activities (Nancy C.).

In one high school, students would use *Understanding Math* to assist them in building the basic skills of math necessary for their high school courses, especially in the area of Algebra. If they reached a point where they could no longer work with the regular curriculum, they could come to the Resource Room and work with the software to review and learn the basic skills necessary for their class. In this way, they could gain the background they were lacking. This allowed these students to go back to their regular classroom and pick up the curriculum with more ease. Students gained the information they were missing and could be more successful with their math curriculum (Maureen F., HRSB).

Students in grades 10-12 use the software, *CABRI-Géomètre* to explore concepts in geometry and to discover graphs and geometric perspectives of functions in Algebra. Students explore trigonometric functions, for example the Law of Sines and Cosines (Antoine J., CSAP).

Science

Planetarium software allows urban Science students to view virtually the night sky in a simulation where otherwise, light pollution near their homes would prevent their seeing many constellations (Nancy C., HRSB). Such software also facilitates astronomical observation despite adverse weather. This application is just one example of the simulation software currently available to public schools in Nova Scotia through the *List of Authorized Learning Resources*.

Every class in an elementary school participated in a GrassRoots project in which each class from Primary to Grade 6 incorporated the IntelPlay™ QX3+ Computer Microscope in their science curriculum. Every student, either individually or in small groups, investigated various topics in Science, using the microscope to make their observations, and then created *PowerPoint* presentations reporting the information they learned. The *PowerPoint* reports were posted on the school website as part of the GrassRoots requirements. The students used ICT as a tool to enhance their learning of the scientific concepts, rather than as an end in itself.

Grade three teachers developed a series of activity centres as part of their study of seeds in Science. Their students worked through various activities: predicting the numbers of seeds in different fruits and testing their predictions; writing a story about a seed's life; measuring pumpkins and investigating the numbers of seeds in different pumpkins; and observing different varieties of seeds under the IntelPlay™ QX3+ Computer Microscope and recording their observations. The students were very enthusiastic about their work and shared their discoveries with the Minister of Education when he visited the school. The grade three teachers are especially interested in developing more science activities incorporating various learning centres, that balance with technology the use of many other learning resources available for their students.

In fact many of the best classroom activities are a blend of technology and traditional teaching tools. In several Nova Scotian schools, the Monarch Virtual Migration project by Journey North provided online tracking of butterflies as they migrated south in the fall and north in the spring. Students were able to create paper butterflies which they mailed to Journey North, who transported them (with thousands of others) to schools in Mexico. These schools 'housed' the butterflies until spring. In spring, each class received back some paper butterflies (identified by their country of origin) from all over North America and beyond. Meanwhile, students could track the real butterfly migration on maps on the Journey North web-site. Students put Monarch stickers on a huge map of North America in the school lobby for the whole school to see. Students demonstrated their learning by giving mini lessons to younger students about the migration and the online project. The project is a great blend of new and old technologies (Nancy B., HRSB).

Children from New England and New Brunswick came to schools in Southwestern Nova Scotia to work with students on Environmental awareness projects. Students travelled to New Hampshire for a series of outings on topics relating to the Gulf of Maine watershed. The students then created presentations and completed their sessions by presenting their *PowerPoint* reports to the Gulf of Maine Council in Portsmouth, New Hampshire. Children used Global Positioning Software (GPS), ArcView and *PowerPoint* to put together a presentation on Birds and Bats. Most of the pictures in the presentations were taken by the children themselves. Activities for

the Gulf of Maine project are ongoing; recent additions include WebQuests and Earth Day materials (Bill C., TCDSB).

Social Studies

Students at elementary, junior and senior high levels are all accessing online information in support of Social Studies curriculum outcomes; they have greater and faster access to more data online, which facilitates analysis, more complex inquiries and higher level thinking.

In the Strait region, for example, a senior high school Geography class used Geographic Information System (GIS) technology to collect original data for a real emergency evacuation plan for their community, then mapped the data and presented it to local authorities. The school continues to work with the municipality to complete new, meaningful research projects for students each years (SAERC).

Before Internet was available in Nova Scotian schools, students in a grade 3/4 classroom used the software, *Sim City*, during rainy lunch times. As a result, nine-year-old students were able to discuss cogently conflicting issues of environmental conservation and taxation levels in their light of their impacts on the results of local elections. Similarly, *Carmen San Diego*, was sometimes used as a classroom collaborative activity in which two students operated the classroom computer and read the scenario and clues. Other students worked the map of the world on the wall; others used encyclopaedias; and still others reference books. Their teacher reports that they achieved the best sense of global geography and international money of any Grade 4 class at their school (Nancy B., HRSB).

It wasn't your typical, "All About Me," Social Studies project for one grade P-3 class on the South Shore. This group of students used a school digital camera to take pictures at home and then created *PowerPoint* presentations for their peers. Even those who normally struggle with writing were motivated by the technology and by the use of their own pictures to tell their story. The editing process was much less onerous using technology, and the high quality of the student products speaks for itself (SSRSB).

Another teacher prepared for his students a simple genealogy chart template that would help student groups in his class tell stories of Acadian family and simultaneously generate a bibliography. The students began their online research at http://genealogynet.com, which led them to other sites, such as the 1837 to1901 censuses, birth, marriage, and death records and the cemetery records of Colchester County, from which they could cut and paste information relating to their selected family. They also consulted genealogy books, maps, and manuscripts. Students reviewed their interim results with the teacher and finally completed genealogy forms for their target families. The forms became the basis of written presentations. Each project had a local map with an arrow showing where selected families first lived. Some students added pictures they took with a school digital camera of the oldest homes and grave stones in Tatamagouche Village. Others researched and displayed pictures of their assigned family's home in both the past and present. The class presented a copy of their photographic archives to the local historical society, whose members were very pleased, and classroom visitors were also impressed by the range and depth of the information assembled by the class on their computer pod. (Norris W., CCRSB).

Groups of Grade 12 students used *Inspiration* software to graphically organize information about the African famine. Information was found using the *EBSCO* online database which is available to all students and teachers in Nova Scotia. Students presented their concept webs to their classmates using video projectors. The students soon realized that the graphics they designed were too complicated to explain. Consequently, they revisited their work to

clarify issues. The process provided an opportunity for students to look for relationships in readings and to identify cross-curricular applications. Students isolated relevant information to create patterns, to examine cause and effect relationships, to note interventions that disrupt famine and conditions contributing to the problem. The process enabled students to read, clarify, find relationships, develop explanations, ask questions, to work as a team, to identify a goal, to revise a project where the response was inappropriate (David S., SRSB).

Elections Canada, Cable in the Classroom and Industry Canada developed a national project challenging schools to develop and produce a short public service announcement on why voting is important. Nova Scotia provincial winners were three Canadian History 11 students and their teacher at the Flexible Education and Learning Centre (HRSB.) To edit this award winning video, the students used equipment supplied to secondary schools across the province as part of the Information Economy Initiative. This technology helped students relate classroom assignments to authentic issues outside their classroom (SSTA Newsletter, Oct. 2004).

Nova Scotia's Canadian History 11 course was developed with a significant online component which includes access to original source documents. All students, regardless of their location, have access to a rich collection of documents and can participate in the study of history using the tools and techniques of the discipline to construct their learning rather than simply reading what others have created (Gardner 2004b).

The Flat Stanley Project is based on the children's book *Flat Stanley*, by Jeff Brown. It allows students from around the world to "visit" other places and learn about them. In return, the students host Flat Stanleys from other locations, providing information and experiences about their environment to send back. The Flat Stanleys are made of paper and decorated by the children. They are then mailed to other participants in the project. When they arrive, they are often taken to many locations of interest and photographed doing a variety of different activities. Flat Stanleys have been on the space shuttle and to the White House. Some classes now send virtual Flat Stanleys, and provide digital "experiences" to send back with them when they go home. Classes around the province in a number of grade levels have set up websites to record the adventures of their Flat Stanleys.

Attitude and Self Concept

Grade 5 students were motivated by teaching others how to use software like *Microsoft Excel* in the context of classroom curriculum; student self-concept and confidence increased because of positive response from their peers. Increased student confidence promotes their achievement of learning outcomes.(Gary Walsh, AVRSB)

A school in Cape Breton used a website project to help the whole school deal with and better understand what happened to one of their teachers who was seriously injured in a car accident. Their website project was conceived to allow students and staff to investigate the nature and treatment of spinal cord injuries so that they could better cope with and understand what has happened to a member of our school community. The website contains information which deals with a variety of issues related to these types of injuries. Students everywhere and at our school in particular will refer to this website to learn what has happened to their teacher and the issues that face her for the future (Hugh M., CBVRSB).

After playing a computer game requiring students to remember where certain items are located on different screens, one boy with Down's syndrome became rather excited the first time he saw the box that the CD came in. He pointed to the map on the back of the box and eagerly identified the various locations where items could be found by Putt-Putt, a character in the game. At no time would he have

seen the whole map on the computer as only one section was shown at any one time. Since he exhibited very low verbal skills at that time, his teacher was amazed that he had the skill and memory to organize those images in his mind. His teacher had higher expectations from that point onwards and relied more on visual cues in presenting him material (Nancy B., HRSB).

Other teachers report that students with special needs have become more motivated and self-directed for a sustained period of time as a result of engagement in an Internet webquest, *Zelda's Zany Zoo*, which features both online and traditional resources. Their presentations at the conclusion of their quests were more complex and varied compared to previous efforts using scissors, glue and Bristol board (Nancy B., HRSB).

Technology is integrated in the Joy Program at one elementary school. A key finding is that students are motivated and eager to learn with technology. The barriers between students disappear; even those who are typically reluctant share and help each other in this mixed ability environment. The high level of interest generated by technology days at the school is an attendance booster, and students willingly give up their recess and lunch times to create with *iMovie* multimedia productions which address communications outcomes by engaging all students in project research, planning and evaluation (Peter M., CBVRSB).

At another school, access to ICT also proved to be a great motivation for learning. Since the school had only one digital video camera and one computer with *iMovie*, students came in before school, after school, lunch, recess, and weekends to record and edit a series of short programs as part of the Language Arts curriculum. Seeing digital video media in action encouraged students who resisted conventional forms of expression, such as writing and speeches, to grab the mouse first. The very students who faced obstacles in learning and social skills, became the most committed learners. A student with dyslexia, for example, took control of his group and produced one of the best videos in Grade 8. Another student who could barely stay in his chair during class was glued to *iMovie* during every spare moment of the day. Another student came alive in front of the camera and worked during every lunch hour to make up for two external suspensions. Students worked without being pushed and many shone for the first time, demonstrating pride in their accomplishments (Ryan, AVRSB).

A student, who did not attend classes on a regular basis and had academic and behavioural issues, was appointed the class photographer. The student was expected to be in class to take the pictures, download them onto the computer and add them to the class website with captions. This previously reluctant student began to not only attend school faithfully but to write regularly as well. Students publishing to external audiences attend more fully to conventions of spelling and grammar: "Hey, this has to be really good. It's going to be published on the Internet." (SSRSB)

A grade 6 student, Peter, who had a history of discipline problems, turned out to have a tremendous aptitude for technology, especially computers. Peter got along extremely well in his school's enrichment program, and produced a DVD on the History of New Waterford which was played at the program's closing banquet to an audience of 150. To complete this project, Peter worked hundreds of hours editing video footage and providing voice over. He worked in the classroom every lunch hour for about 4 months. His discipline problems were a thing of the past. He was now focussed and was doing something he enjoyed and for which he had a great aptitude. Local newspaper stories documented his project, and little Peter's self esteem went through the roof (Lowell C., CBVRSB).

A new teacher of Grade 12 Law was challenged to complete the course requirements given that the students did not seem interested in the

traditional methods of teaching law and were not engaged in the course. After cooperatively planning the course with the teacher-librarian, they divided the class into six groups to prepare a videotape of an entire criminal case from the crime to the trial and sentencing. The students were required to research the crimes, write a script, prepare a storyboard, collect props, prepare a stage, act, videotape, direct, edit, burn to a CD and present their case to the class. Students were totally engaged in the process and worked cooperatively to produce well-documented video cases. The teacher said "two thumbs up"; students were immersed and excited about their law course (Pat M., HRSB).

Sometimes the benefits of technology are unexpected. One teacher had a student who had learning problems related to a brain injury. The school provided a recycled computer for him to use. At first, when there were technical problems, he would say only, "It's broke," or "It won't work". However, after working with it for several months, he would approach his teacher and explain, "There's a problem with the computer. It won't print. I tried the cables and power switches. I think the problem is..." Through his exposure to ICT, this student developed problem solving and communication skills that transferred to other situations (Nancy B., HRSB).

From students at a newly constructed technology-rich school:

> Technology has played a major part in improving my marks in my school work. For example using PowerPoint has made a huge difference by making it easier to present and organize the material. Technology gives me more confidence in myself. It has also helped me with spelling, grammar, and punctuation when writing or doing an assignment. (Laura B., Grade 12, CCRSB)

> Where do I begin? It has made a huge difference in my school work. It has brought up my average by at least 15% in subjects I did not do well in. I do a lot better now because of the new technology in the school. It helps for research projects, projects in general, speeches and assignments (Chris W., Grade 10, CCRSB).

> Technology has made school a lot better for me because it helps me learn quicker and makes doing projects a lot more exciting (Jacob J., Grade 11, CCRSB).

Students in one high school used their skills in video editing from the Technology 11 course to produce high quality videos and DVDs as a fund raiser from the Congrès mondial acadien. The students gave up their own time in the summer to use their expertise learned from class in producing videos and DVDs (Ron L., CSAP).

The benefits of ICT are not limited to students, either. One teacher reported that the IEI initiative renewed his enthusiasm for the teaching profession while providing a "light switch " which "turned on" many students to this new opportunity. In his case, new classroom technology provided a flexible tool to reinforce the GIS concepts that he was teaching in Geography. At the same time his students, obtained an engaging, electronic environment in which to research and present their work. Together, this teacher and his students have created an innovative relationship with their community that informs their learning. For example, the class has created a digital map of the town, with a data set that allowed them to plot local homes and businesses, street names and civic addresses, fire hydrants, schools, and even the location at which the greatest number of car accidents occur.(Doug B., SSRSB)

In another case, a successful elementary/middle school teacher with more than twenty years

experience had resisted in-service training associated with the Information Economy Initiative. His negative attitude concerning ICT deterred student learning. Nevertheless, colleagues persuaded this teacher to participate with them and their students in professional development to support an interdisciplinary unit which integrated technology. As the reluctant teacher began to see the positive impact of ICT on student learning in this unit, he and his students began actively to lead the exploration of technology both within and beyond the classroom, particularly professional development experiences involving multimedia. His attitude is now more than positive; it is proactive, and he is recognized in his school as an ICT leader (Jim P., AVRSB).

Assistive Technology

All students who have verbal coding problems—at every grade level—can be helped with a text reading program. In addition, *Inspiration* software provides an effective organizing structure for students with visual learning difficulties (Ted, HRSB).

Technology has finally given teachers a way to allow many of these students to express themselves when they cannot do so by the traditional methods. In the case of many students with Individual Program Plans (IPP), computers help them achieve their academic plans, while enhancing their social status within the class, so that they more easily develop friendships. Computers allow students at every achievement level in the classroom to experience success, whatever it means to each individual student. Computers provide greater motivation for all students and alternative ways to achieve curriculum outcomes (Lise D, HRSB).

Elementary students with limited motor control can use ICT adaptations that allow them to launch and manipulate applications; open, save and print documents; and perform word processing. They take part in novel studies and participate in other, hitherto inaccessible classroom activities, such as listening centres, cutting and pasting information, and interviewing fellow students using voice output communication aids. One nonspeaking grade seven student with beginning literacy skills, for example, used a picture symbol adapted keyboard with programmed words and phrases to create a written document in response to a science unit on gravity. She then entered the document into a talking word processing program, so that she was able to present an oral report to her teacher by activating the "read" command within the program (Elizabeth P., HRSB).

Another teacher used the predictive software, *CoWriter*, with two students on IPP for Language Arts. For particular projects or especially review items, he would create on the classroom computer project/question sheets with empty text fields, so that the two IPP students could use CoWriter to create text responses and insert them in the corresponding text fields. The students quickly learned to manipulate the software, so it became a good way for them to participate at a more grade appropriate level. They also demonstrated greater enjoyment and engagement in class (Chris, SRSB).

One elementary student with disabilities became the class expert in *PowerPoint* and was able to help his peers. Other students came to be in awe of him, as the majority of them had little experience with this software. *Write:Outloud* and *CoWriter* have helped Kyle to participate regularly in classroom assignments. Perhaps for the first time, he sees himself as successful (Carole-Anne, CBVRSB).

Another student in grade 3 has been using the program, *Inspiration*, with an audio adaptation to organize his work, and his teacher is amazed to see the confidence he has gained by doing so. He has started confidently coaching peers in the application, when before, his classmates ignored him because of his speech impediment (Sue. T-F., SSRSB).

Models for Professional Development

A teacher, who currently has a 60% teaching assignment, reported difficulty finding professional development opportunities which were conducive to her schedule. During development of a Grade 4 curriculum resource, she was introduced to WebCT, an asynchronous online learning management system. She reports that she has subsequently found this system an effective, flexible means of providing curriculum support directly for teachers, by teachers. Her experience with it has left her enthusiastic and rejuvenated (Susan C., HRSB).

Staff of Cape Breton Victoria Regional School Board report positive results from a partnership with University College of Cape Breton to deliver professional development to public school teachers. Prior to the partnership, overall teacher comfort level was low and PD money was scarce. The partnership provided PD facilitators, teacher release time for Professional development, access to good computer labs and a solid Internet connection. The project was a catalyst to move from basic computer skills to teaching strategies related to the integration of a cluster of four classroom computers (Rick S., CBVRSB).

Chignecto Central Regional School Board uses a model in which a mentor travels with a mobile lab of 15 laptop computers. Each mentor works for up to 6 weeks with teachers in a particular school on projects identified by the teachers themselves. The summer technology integration institute and technology mentors are money well spent and provide necessary support for very busy teachers. When the board covers the cost, it sends a clear message that the board believes that technology is important and that they understand that with rapid changes in technology, continuous professional development and mentor support is absolutely necessary. If we wish to continue to develop technology skills, we must continue to support what works (Peter M., CCRSB).

Halifax Regional School Board has started a new model for professional development. One teacher from each Junior High has been identified as a strong classroom teacher and is pulled out for 14 days of intensive professional development throughout the school year. Over the course of the year, the teacher is also given 14 days to work with teachers in her school on technology integration projects.

Although little formal research has been conducted on implementation of ICT in Nova Scotia, the anecdotal evidence reported in this section parallels findings in the formal research as reported in Section A; where students have sufficient access, teachers have appropriate technical and professional support and where the application or project is directly linked to curricular outcomes in the Public School Programs, students tend to be actively engaged in their learning.

Section C: Discussion

There has generally been insufficient rigorous research to definitively evaluate the use of information technology in public schools. At the same time, there has been such significant change in the types and extent of ICT-based learning experiences available to students in public school classrooms, that much of the earlier research is irrelevant.

It is worth noting that computers are well used in many early elementary classrooms in Nova Scotia in spite of a lack of formal support below grade 3. All students in Nova Scotia potentially have access to high speed Internet in their classrooms, have access to computers of a currency and in sufficient quantity which rival most jurisdictions, and have access to a wide range of open-ended software which supports higher levels of understanding. Particular emphasis on ICT-integration within the curriculum has occurred at grades 4-6 and grades 7-12. The research and anecdotes from teachers in Nova Scotia indicate that students are excited when engaged in authentic learning activities.

There continue to be questions about the correct ratio of students to computers in public school use. It is important to note that any overall ratio can only be construed as averaging many types of usage. Computer labs used for teaching specialized technology courses tend to have 1:1 or 1:2 ratio of computers to students, while for data gathering in a science lab, it may be sufficient to have four stations for a class (that is, one computer to seven students.) For general classroom use, consensus seems to favour ratios of computers to students which are better than 1:5. The current focus of the IEI-Extension is appropriately in grades 7-8 where the ratio of current computers to students was 1:8.6 (March 2004.) The ratio at 4-6 was reported as 1:5 and at grades 10-12, the ratio including computers in specialized labs was reported as 1:3.

Howard Gardner described a theory of seven types of intelligences including linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, interpersonal and intrapersonal intelligences (later expanded to include naturalist and existentialist intelligences) (Gardner 2004a). Presumably, student learning can blossom when targeted at a student's natural intelligences. Initially, computer-based learning activities focussed only on mathematical-logical and verbal-linguistic intelligences. However, with the multimedia computers and software which are available currently in Nova Scotia classrooms, as well as interaction in the classroom and online, students should have many opportunities to employ visual-spatial, musical, interpersonal and intrapersonal intelligences as well. Students thus expand their learning in ways which favour intelligences which have already been developed as well as engaging in learning experiences which help to develop other intelligences.

Other authors refer to auditory, visual and tactile/kinesthetic learning styles. Schools have typically catered to auditory and to a lesser extent to visual learning preferences. Using multimedia software to create and explore concepts under study may well engage learners with other learning preferences and help learners to develop familiarity with less preferred learning styles.

The broad subject of assistive technology (AT) for students with special needs will be described in other documents, but it is worth noting that a number of ICT stories volunteered by teachers in Nova Scotia highlight the use of AT to permit students to engage fully in learning alongside students without special needs. Research papers support this claim, but note the requirement for support from the teacher.

Research studies document the implementation of ICT in several subject areas, notably language arts and mathematics, but are silent on many more. Skills such as writing, organizing, publishing and problem solving have been components of many research studies and can be

generalized across the curriculum.

Some research would suggest that computer-assisted learning may well be no better than personal contact with high quality teachers (Morgan 2002), but with the diversity of today's classrooms, computers may be used effectively to assist a teacher to cope with widely diverse student needs, assuming software is carefully chosen and targeted to the needs of individual learner. This type of change requires a shift in pedagogical style; modifications in pre-service preparation of teachers; and a framework for integrating ICT with sound instructional practices. Commitment to the use of a powerful tool on the part of students and teachers is required in order to take advantage of the potential for improved learning and teaching.

Even though recent graduates of teacher training institution are more likely to be fluent with ICT, professional development and support must be provided for cooperating teachers in order to ensure effective models of classroom ICT integration are consistently present during classroom student teacher experiences. In addition, education faculty must routinely model effective use of ICT in pre-service teacher education programs. Student teachers are unlikely to adopt techniques they do not see employed, and employed well. In addition, there is an anticipated turnover of 10-12% per year in the teaching population in Nova Scotia over the next few years requiring a continued focus on professional development to assist new entrants to the profession.

School continues to have a role in providing equitable access to resources including ICT for students from rural and lower socio-economic status (SES) backgrounds. Concerns have been expressed about inclusion of females and students from minority and ethnic groups. In Nova Scotia, current enrollment of females in courses such as Computers 12 and Technology Education is less than one third. Specific strategies must be developed to encourage more equitable participation in all aspects of schooling by all learners.

Although there has been little formal research concerning the integration of ICT in Nova Scotia, anecdotal information is consistent with findings reported in the literature.

At the beginning of this document, four questions formed the framework upon which much of the research was performed. This paper has attempted to answer these questions particularly as they apply to the Nova Scotia context.

1. Is there a research basis for use of information and communication technology (ICT) in public school classrooms?

In summary, and in spite of the caveats on the quality of some of the research studies themselves, there is evidence that effective integration of information technology can assist students in the development of skills and knowledge in curricular areas. It can significantly enhance research skills, motivation and student and teacher attitudes towards the learning process.

2. Are these research findings reflected in ICT integration in schools in Nova Scotia?

Although there has been little formal research concerning the integration of ICT in Nova Scotia, anecdotal information is consistent with findings reported in the literature.

3. What conditions are necessary to enable effective use of ICT?

The following among the best practices which have been identified to integrate ICT within the curriculum:

- ICT is implemented based on a clear vision and expectations for learners and teachers;
- technology is supplied with curriculum-based software and learning activities;

- there is regular access to technology in classrooms (ratio better than 1:4 computers to students);
- skilled teachers model constructivist processes
- professional development is provided for teachers
- professional development closely aligns with curriculum outcomes which teachers will introduce in their classrooms;
- professional development and support for classroom teachers uses a mentorship model in which teachers are working directly with other teachers in their own classrooms;
- local school administrators are included in and engaged in professional development for teachers;
- students function as peer helpers;
- project based learning provides opportunities for students to use technology to explore and solve authentic problems which are directly linked to curriculum outcomes;
- webquests are used to guide student exploration and use of the Internet;
- extended class periods are available for indepth exploration;
- consistent technical support is available to support classroom integration of ICT;
- networks are sufficiently robust and fast enough to encourage student and teacher use of online resources and learning activities.

4. How can lessons from exemplary classes be transferred to other classrooms and schools?

Continue the shared management structure between the Department of Education and school boards. The RoBoTS structure provides a face-to-face and online forum for sharing technical information and professional development resources.

Promote in-class mentoring through collegial relationships with other teachers to which teachers have responded more positively than pull-out models of professional development.

Embed technology-related outcomes within other curriculum documents and professional development activities.

Section D: Recommendations

1. Develop a multi-year strategic plan to integrate information and communication technology within the curriculum with designated funding to ensure that there is:
   infrastructure (equipment, software, networks, technical support)
   access in classrooms and other learning spaces as required
   professional development for pre-service and in-service teachers which integrates and models effective use of ICT, and
   opportunities for educators to share best practices.

2. Integrate effective use of ICT within the teacher supervision plan and link the integration of ICT to school improvement plans

3. Embed ICT outcomes and strategies within curriculum documents.

4. Conduct a need assessments to determine specific professional development needs for teachers and then follow-up to determine the effectiveness of what was provided in transfer to classroom practice.

5. Continue to manage implementation of technology in public schools through a shared Department-school board planning model.

Bibliography

Angrist, Joshua and Victor Lavy (2002). *New Evidence on Classroom Computers and Pupil Learning* in **The Economic Journal**, 112, pp 735-765.

Apple Computer Inc.(2002). *The Impact of Technology on Student Achievement: A Summary of Research Findings on Technology's Impact in the Classroom* [Electronic version]. Retrieved from http://www.apple.com/education/research/

Baker, Thomas R. (2002) *Extending Scientific Inquiry with GIS: Research Results*. (Paper 5046, ESRI Education Conference.)

Barron, Ann E.; Kemker, Kate; Harmes, Christine; Kalaydjian, Kimberly (Summer 2003). *Large-Scale Research Study on Technology in K-12 School: Technology Integration as It Relates to the National Technology Standards*. **Journal of Research on Technology in Education**, Vol. 35 Issue 4, p489

Becta ICT Research (2004), British Educational Communications and Technology Agency. Online at http://www.becta.org.uk/research

Berson, Michael J. and Peter Balyta (May 2003). *Integration of Technology in the Social Studies*, Texas Instruments Inc.

Breuleux, Alain and Thérèse Laferrière (2002), *Capacity Building within and across countries into the effective uses of ICTs*. **2002 Pan-Canadian Education Research Agenda Symposium**. Montreal

Bussière, Patrick and Tomasz Gluszynski (2002). *The Impact of Computer Use on Reading Achievement of 15 year Olds*. **2002 Pan-Canadian Education Research Agenda Symposium**. Montreal

Cameron, Tom (2004) *Geographic Information System Technologies as an Educational Tool in Ontario Schools*. (Thesis: Queens University)

Canadian Regulatory Telecommunications Council (November 2004). *Report to the Governor in Council (November 2004). Status of Competition in Canadian Telecommunications Markets: Deployment/Accessibility of Advanced Telecommunications Infrastructure and Services* **check name.

Canadian Teachers' Federation (2003). *An Investigation of the Integration of Information and Communication Technology into Canadian Schools and Classrooms: Phase 1 - Research and Feasibility Study*. Ottawa.

Conference Board of Canada (July 2003). **Solving Canada's Innovation Conundrum: How Public Education Can Help**. Issue Statement #1 (Publication 417-03).

Cox, Margaret et al (2003). *ICT and Attainment: A Review of the Research Literature*. **ICT in Schools Research and Evaluation Series No. 17,** Department for Education and Skills, United Kingdom. British Educational Communications and Technology Agency. Retrieved from http://www.becta.org.uk

Cox, Margaret et al (2003). *ICT and Pedagogy: A Review of the Research Literature*. ICT in Schools Research and Evaluation Series No. 18, Department for Education and Skills, United Kingdom, 2003.

British Education Communications and Technology Agency. Retrieved from http://www.becta.org.uk

Coiro, Julie (February 2003). *Reading comprehension on the Internet: Expanding our understanding of reading comprehension to encompass new literacies*, **Reading Teacher**, Vol. 56 Issue 5, p. 458.

Corbett, Bradley A. And J. Douglas Wilms (2002). *Canadian Students' Access to and Use of Information and Communications Technology*. **2002 Pan-Canadian Education Research Agenda Symposium.** Montreal.

Dickard, Norris, Editor (2003). **The Sustainability Challenge: Taking EdTech to the Next Level** (New Yrok, Center for Children and Technology).

Disessa, Andrea A (2000). **Changing Minds: Computers, Learning and Literacy.** MIT.

Elchuck, Larry M. (1992) **The Effects of Software Type, Mathematics Achievement, Spatial Visualization, Locus of Control, Independent Time of Investigation, and Van Hiele Level on Geometric Conjecturing Ability.** (Pennsylvania State Univ, thesis)

Test scores fuel Maine laptop debate in eSchool News October 2004 p. 29

Fournier, Luc and Kim MacKinnon (1994). *Educational Opportunities on Canada's Information Highway: The Use and Deployment of Communications Technologies in Education*. Ottawa: Industry Canada.

Fuchs, Thomas and Ludger Woessmann (September 2004). *What Accounts for International Differences in Student Performance? A Re-Examination Using PISA Data*. Discussion Paper No. 1287. Forschungsinstitut zur Zukunft der Arbeit / Institute for the Study of Labor. Retrieved from http://www.iza.org/

Funkhouser, Charles (Winter 2002/2003). *The Effect of Computer-Augmented Geometry Instruction on Student Performance and Attitudes* in **Journal of Research on Technology in Education**, Vol. 35 Number 2, p.163-175.

Gardner, Howard. (2004) **Frames of Mind: The Theory of Multiple Intelligences.** (New York: Basic Books).

Gardner, Howard. (2004) **The Unschooled Mind: How Children Think and How Schools Should Teach.** (New York: Basic Books).

Goldberg, Arnie, Michael Russell and Abigail Cook (2003). *The Effect of Computers on Student Writing: A Meta-Analysis of Studies form 1992 to 2002*. **The Journal of Technology, Learning and Assessment**, Volume 2, Number 1, February 2003.

Goodison, Terry (2002). *ICT and attainment at primary level*. **British Journal of Educational Technology**, Vol. 33 No 2, pp 201-211.

Haughey, Margaret (2002). *Canadian Research on Information and Communications Technologies: A State of the Field*. **2002 Pan-Canadian Education Research Agenda Symposium**, Montreal.

Higgins, Steve. 2003. *Does ICT Improve Learning and Teaching in Schools?* London: British Education Research Association, August 2003. Retrieved from http://www.bera.ac.uk/publications/pdfs/ICT PUR MB r-f-p 01Aug03.pdf

ICT in schools: The impact of government initiatives five years on. Office for Standards in Education, United Kingdom, May 2004.

Integrating Literacy and Technology in the Curriculum: A Position Statement of the International Reading Association, adopted by the Board of Directors, September 2001 (2002)

Jeroski, Dr. Sharon (July 2003). *Wireless Writing Project, School District No. 60 (Peace River North) Research Report: Phase II.* Retrieved from http://www.prn.bc.ca/FSJ_WWP_Report03.pdf

Karsenti, Thierry et al (2002). *Integrating ICT's in teacher tr@ining: a challenging balance.* **2002 Pan-Canadian Education Research Agenda Symposium**, Montreal.

Legault, Fréderic and Thérese Laferrière (2002). *Impact of a networked computer-assisted project-based pedagogy on motivational beliefs and work involvement of secondary-level students.* **2002 Pan-Canadian Education Research Agenda Symposium**, Montreal.

Looker, E. Dianne and V. Thiessen (2002). *The Digital Divide in Canadian Schools: Factors Affecting Student Access to and us of Information Technology.* **2002 Pan-Canadian Education Research Agenda Symposium**, Montreal.

MacArthur, Charles A, et al (2001). *Technology Applications for Students with Literacy Problems: A Critical Review,* **The Elementary School Journal**, V 101 n3.

MacDonald, G. Jeffrey (2004). *Contrarian Finding: Computers are a drag on learning* in **The Christian Science Monitor**, December 6, 2004. Retrieved from http://www.csmonitor.com/2004/1206/p11s01-legn.html

Mahoney, Sarah (March 5, 2003), *Laptops Win Over the Skeptics, Even in Maine*, New York Times.

Morgan, John et al (2002). *The Use of Computer Technology for Literacy Intervention: Factors contributing to the use of computer-delivered skills-based literacy software.* **2002 Pan-Canadian Education Research Agenda Symposium**, Montreal.

National Center for Education Statistics. *Science Highlights 2000: the Nation's Report Card.* Retrieved November 3, 2004 from: http://nces.ed.gov/nationsreportcard

Norris, Cathleen; Sullivan, Terry; Poirot, James; Soloway, Elliot (Fall 2003). *No Access, No Use, No Impact: Snapshot Surveys of Educational Technology In K-12.* **Journal of Research on Technology in Education**, Vol. 36 Issue 1, p15.

Nova Scotia Department of Education (2002). *Information Economy Initiative ICI-School Project: Interim Final Report to IEI Council, March 31, 2002.* Nova Scotia Department of Education, Halifax.

Nova Scotia Department of Education (1999). *Vision for the Integration of Information Technology in Public School Programs within the Nova Scotia Public School System.*

NCREL (North Central Regional Educational Laboratory.) (2004) *Computer-Based Technology and Learning: Evolving Uses and Expectations*. Retrieved from http://www.ncrel.org/tplan/cbtl/toc.htm.

O'Neill, Lucinda M. and Bridget Dalton (2004). *Thinking Readers Part II: Supporting Beginning Reading in Children with Cognitive Disabilities through Technology*. Retrieved July 26, 2004 from http://www.cast.org/udl/index.cfm.

Passey, Don and Colin Rogers, with Joan Machell and Gilly McHugh (2004). *The Motivational Effect of ICT on Pupils*. Research Report RR523, Lancaster University. Produced for Department for Education and Skills, United Kingdom. Retrieved from http://www.dfes.gov.uk/research.

Peck, Craig et al (February 2002). *Techno-Promoter Dreams, Student Realities*. **Phi Delta Kappan**, V83, n6.

Ross, John D., Tammy McGraw and Krista Burdette (January 2003). *Towards an Effective Use of Technology in Education: A Summary of Research*. Charleston, WV: AEL Inc. (Appalachia Educational Laboratory).

Slater, Alan, *Using Computers in Maths Lessons: Best practice* (Oxford: Department of Educational Studies, 2004)

Sokoloff, David R. and Ronald K. Thornton (Sept. 1997). *Using Interactive Lecture Demonstrations to Create an Active Learning Environment*. **The Physics Teacher**, Vol. 35, pp. 940-947.

Sokoloff, Heather (January 30, 2003). *Quebec school board first to equip all students with laptops: N.B. watches closely*. **National Post**

Solomon, Gwen (April 2002). *Digital Equity: It's Not Just about Access Anymore*. **Technology & Learning**, V22, issue 9, p. 18.

Statistics Canada (2003). *Home Internet Use Survey* in **The Daily**, Thursday, September 18, 2003. Retrieved from http://www.statcan.ca/Daily/English/030918/d030918b.htm.

Statistics Canada (2002). *Computer Access at school and at home* in **The Daily**, Tuesday, October 29, 2002. Retrieved from http://www.statcan.ca/english/edu/feature/computer.htm.

Stevenson, Ian (2004). *Measures for Assessing the Impact of ICT Use on Attainment*. British Education Communications and Technology Agency. Retrieved from http://www.becta.org.uk

A systemic review of the impact of ICT on literature-related literacies in English, 5-16. (London: EPPI-Centre, University of London, January 2004)

A systemic review and meta-analysis of the effectiveness of ICT on literacy learning in English, 5-16. (London: EPPI-Centre, University of London, November 2003)

A systemic review of the impact of ICT on students and teachers of the use of ICT for assessment of creative and critical thinking skills. (London: EPPI-Centre, University of London, July 2003)

Tao, Liqing and David Reinking (2000). *Issues in Technology: E-mail and Literacy Education*, **Reading and Writing Quarterly**, 16.

Thiessen, Victor. (2004) **Performance and perception: Exploring gender gaps in human capital skills.** (Seminar, Dalhousie University, Oct. 15, 2004)

Ungerleider, Charles S. and Tracey C. Burns (2002), *Information and Communications Technologies in Elementary and Secondary Education: A State of the Art Review*. **2002 Pan-Canadian Education Research Agenda Symposium**. Montreal.

Venezky, Richard L. and Cassandra Davis (March 2002). *Quo Vademus? The Transformation of Schooling in a Networked World*. Retrieved July 12, 2004 from http://waldorf.eds.udel.edu/oecd/cases/CS_SummaryDraft8c.html

Wenglinsky, Harold (1998). *Does It Compute? The Relationship Between Educational Technology and Student Achievement in Mathematics*. Princeton, NJ: Educational Testing Service.

Williams, PJ et als. *Studio Physics at Acadia University*, **Physics in Canada** (March/April 1997)

Williams, PJ et als *The Effectiveness of Computer-Based Studio Teaching of Physics*, **Physics in Canada** (July/August, 2003)

Wolfe, Patricia. **Brain Matters: Translating Research into Classroom Practice.** (Alexandria, VA: ASCD, 2001)